2022 Lake Windermere Water Quality Report

lake windermere ambassadors
healthy water for healthy communities

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Executive Summary

The Lake Windermere Ambassadors direct a Community-Based Water Monitoring and Citizen-Science Education program within the Lake Windermere watershed. 2022 marked the sixteenth year of lake monitoring since the Lake Windermere Project began collecting water quality data in 2006.

In 2022, the Lake Windermere Ambassadors water quality monitoring program collected physical and chemical water quality parameters at three sample sites on Lake Windermere once weekly during the summer, from late May to September. The lake sampling regime included water temperature, turbidity/clarity, pH, conductivity, depth, and dissolved oxygen. Total dissolved phosphorus and total phosphorous were collected monthly from May to August. In addition, the LWA monitored substrate samplers at six sites on the east side of Lake Windermere for invasive mussels. Tributary flows and water quality were monitored in Windermere Creek and Abel Creek. In partnership with the Interior Health Authority, *E. coli* data was collected at public swim beaches weekly, from June until September, excluding weeks with a statutory holiday Monday.

Findings from 2022 show Lake Windermere's water quality supports aquatic life and recreation. Four of the eight parameters deviated from the Ministry of Environment objectives, including temperature, turbidity, specific conductivity, and total phosphorus levels. Two of the public swim beaches (Windermere and Kinsmen) met Interior Health Authority guidelines for recreational water quality during all sample collection dates in 2022. James Chabot public beach exceeded the Interior Health recommended limit of 200 *E. coli* colonies on one occasion. On July 11th, 350.93 colonies of *E. coli*/100mL were found at the East sample site, and 5100 colonies of *E. coli*/100mL were found at the central site. Samples taken the following week showed *E. coli* colonies at James Chabot beach to be within recreational water quality guidelines again and the reason for the high readings is unknown. The newly developed waterbird survey protocol and the investigative report found 19 species observed, 953 individuals, with several of them being rare sightings and species at risk. Invasive mussel larvae (veligers) were not detected in Lake Windermere as sampled by the Province of BC in 2022 (BC Conservation Officer Service, 2022).

Our major funders for this project and its final report include the Columbia Valley Local Conservation Fund, BC Conservation and Biodiversity Awards, the District of Invermere, the Regional District of East Kootenay, Columbia Basin Trust, EcoCanada, BC Community Gaming Grants, BC Hydro, the Columbia Valley Community Foundation, the TD Friends of Environment Foundation, Totem Charitable Foundation, and Canada Summer Jobs.

1. Introduction

Lake Windermere is one of two headwater lakes of the Columbia River in Southeast British Columbia, Canada. The lake is a long widening of the Columbia River, with an average depth of ~3-4m (10-13ft).

Birds, fish, and wildlife depend on the lake and its outflows into the Columbia Wetlands. Historically, Lake Windermere has supported several fish species and is used by hundreds of species of resident and migratory birds (McPherson & Hlushak, 2008). The Columbia Wetlands are of international importance because it is one of the vastest intact wetlands in North America (Ramsar, 2004).

Humans depend on Lake Windermere for social, cultural, environmental, and economic values. Not only is it a drinking water source, but the lake is heavily utilized for recreation, motorized and non-motorized, in the summer and winter, for business opportunities, and for traditional values.

1.1 Climate

Lake Windermere sits within the Southern Rocky Mountain Trench in the Interior Douglas Fir (IDF) biogeoclimatic zone (Braumandl & Curran, 2002). The region is temperate and experiences all four seasons, characterized by relatively mild, cool winters and dry, hot summers.

Average annual precipitation is 300-400 mm, and most rainfall historically occurs between May and June. Spring freshet usually occurs between late May and early July.

The year's warmest days have historically been recorded in July and August. The 2021 season varied from 2020 and 2019, which were hot summers. In 2021 there was significant forest fire activity, minimal summer precipitation, and a heat dome where air temperatures in June exceeded 45ºC, which meant the hottest days were recorded outside the typical months of July or August. In 2022 there was a delay in warm temperatures in the spring, in addition to a winter with one of the deepest snowpacks in years.

1.2 Watershed Characteristics

Lake Windermere sits at approximately 800masl and is bordered East and West by two distinct mountain ranges, the Rockies and the Purcells. The lake flows from South to North as part of the main channel of the Columbia River, which begins at the North Shore of Columbia Lake, approximately 20km upstream. Lake Windermere flushes on average every 47 days, contributing to its relatively good water quality (McKean & Nordin, 1985).

The main tributary entering Lake Windermere is Windermere Creek, a fourth-order mountain stream with a watershed that drains an area of approximately 90 km² (NHC, 2013). Some significant developments within the Lake Windermere watershed include an active gypsum mine, active and historical forest harvesting, forest service roads, roads and a highway, agricultural and grazing activities, golf courses, and urban and residential development (McPherson et al., 2014).

1.3 Community-Based Water Monitoring

Concerns about increased development and changes to Lake Windermere in the early 2000s prompted the creation of a community-based water quality-monitoring program and watershed stewardship education initiative in the form of the Lake Windermere Ambassadors.

The Lake Windermere Ambassadors (LWA) is a community-led, charitable non-profit society formed in 2010 to protect Lake Windermere in perpetuity. The LWA has overseen a Community-Based Water Monitoring program on Lake Windermere since their inception, using the assistance of volunteers and essential baseline data collected by Wildsight's Lake Windermere Project. Since 2010, the LWA has added to the monitoring program based on needs and available resources, including tributary monitoring, invasive species monitoring, and wildlife surveys.

From 2006 to 2009, the Lake Windermere Project worked to assess the quality of Lake Windermere's waters for wildlife and human recreational uses. In 2010, the BC Ministry of Environment took those four years of data and determined an updated list of Water Quality Objectives for Lake Windermere. These objectives are a benchmark against which the LWA compares present conditions to evaluate whether the lake water quality suits recreational and ecological needs. By testing lake water quality weekly in the summer, the LWA has thirteen years of water quality data for Lake Windermere. This data allows the LWA to detect seasonal and annual changes in water quality and to communicate information about Lake Windermere to help inform sustainable watershed planning and restoration initiatives in the Upper Columbia watershed.

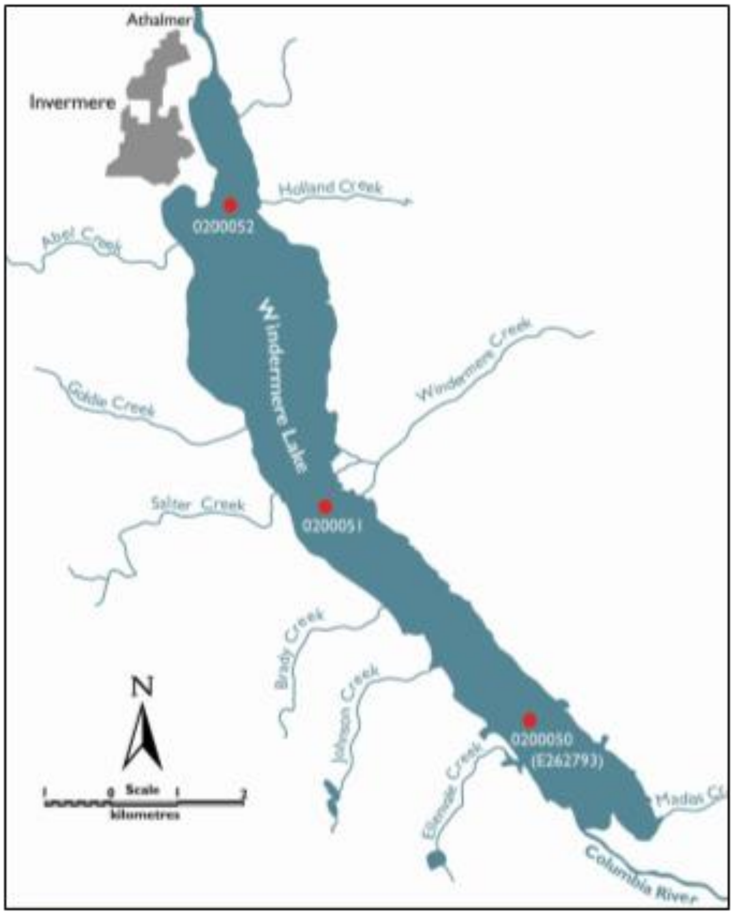


Figure 1: *Lake Windermere Sampling Sites: North (0200052), Middle (0200051), and South (0200050).*

1.4 Sample Sites

Water quality is sampled at three locations on Lake Windermere, historically monitored by the BC Ministry of Environment and the Lake Windermere Project. These locations include North (Timber Ridge/Fort Point), Middle (Windermere) and South (Rushmere) sample sites (Figure 1).

2. Lake Windermere Water Quality Results

2.1 Temperature

Overview

Water temperature is critically essential to lake health as it directly impacts water chemistry (such as: dissolved oxygen, specific conductivity, water density) and influences the rate of chemical and biological reactions. Which, in turn, impacts the ability of aquatic life to grow, survive, and reproduce in each environment (Alberta Regional Aquatics Monitoring Program, 2008).

Due to the it’s shallow depth, Lake Windermere has a naturally elevated temperature relative to other freshwater lakes (Neufeld et al., 2010). Unlike deep lakes, Lake Windermere does not stratify into different layers of temperature and density within the water column (McKean & Nordin, 1985).

Warm and clear water makes Lake Windermere a desirable lake for human recreation. However, average summer water temperatures have historically exceeded the BC Ministry of Environment's (MOE) temperature Guidelines for protecting freshwater aquatic life (Neufeld et al., 2010). For example, many freshwater fish species observed in this Lake have optimum temperatures below 18°C for rearing, spawning, and incubation (Ministry of Environment, 2017a). In contrast, historical monthly water temperatures in Lake Windermere have been recorded up to 25°C (Neufeld et al., 2010).

To adjust for the naturally warmer temperatures in Lake Windermere, the MOE (Ministry of Environment) has set the maximum allowable average monthly water temperatures at 20°C, 25°C, and 23°C in June, July, and August, respectively (Neufeld et al., 2010). These guidelines are based on the MOE recommendation that lake water temperatures should remain within ± 1°C of natural conditions.

Results

The highest water temperature in 2022 was 23.9°C, recorded on August 2nd at both the middle and north upper sample sites (Figure 2a). On the same day, the north lower site was recorded at 23.8°C, and the south site was 21.6°C. This highest day was only half a degree cooler than 2021, where the highest temperature was 24.3°C, recorded on June 29th at the middle sample station (Figure 2a). The difference between the two years was the timing of the high-water temperatures. In 2021 the warmest days were in late June, whereas in 2022, the water temperatures did not reach 20°C until the end of July. However, in 2022 the temperatures remained high until the end of August.

There was only one instance when the average water temperatures exceeded the MOE maximums: August 2nd. The average temperature was 23.3°C and only exceeded the MOE maximum by 0.3°C. Even though the average temperatures did not exceed the MOE maximum to the same extent they did in 2021, the overall seasonal average was relatively high, especially towards the end of the season. An interesting point of note is that on June 28th, the average water temperature went from 16.3°C to 19.4°C and the following week dropped to 17.5°C. The changes over this timeframe are a 3°C increase over a week, followed by a 2°C drop over another week. Interestingly, these temperature drops coincide with increases in turbidity (Figure 4a), with an average turbidity reading of 5 NTU on June 21st and 3 NTU on July 5th. Therefore, the severe drops in temperatures, in addition to the increased turbidity, could be indicators of freshet or seasonal discharge from the surrounding tributaries.

The 2022 season had the third-highest water temperature average recorded over the past ten years, which was 18°C. The two highest seasonal average water temperatures were recorded in 2021 at 19.7°C and in 2015 and were 19.0°C. Figure 2b shows the seasonal water temperature averages from 2011-2022. The data for the season's sampling duration varied over the 11 years, so to get an accurate comparison between seasonal water temperature averages, the averages were taken between June-august sampling dates. Even with these adjustments, 2021 had the highest average of 20.4°C, and 2022 and 2015 both had the second-highest averages at 20°C (Figure 2b). The general trend in average seasonal water temperatures over the last 11 years is an increase in temperature of 1.7°C, from 18.4°C to 20.1°C (Figure 2b).

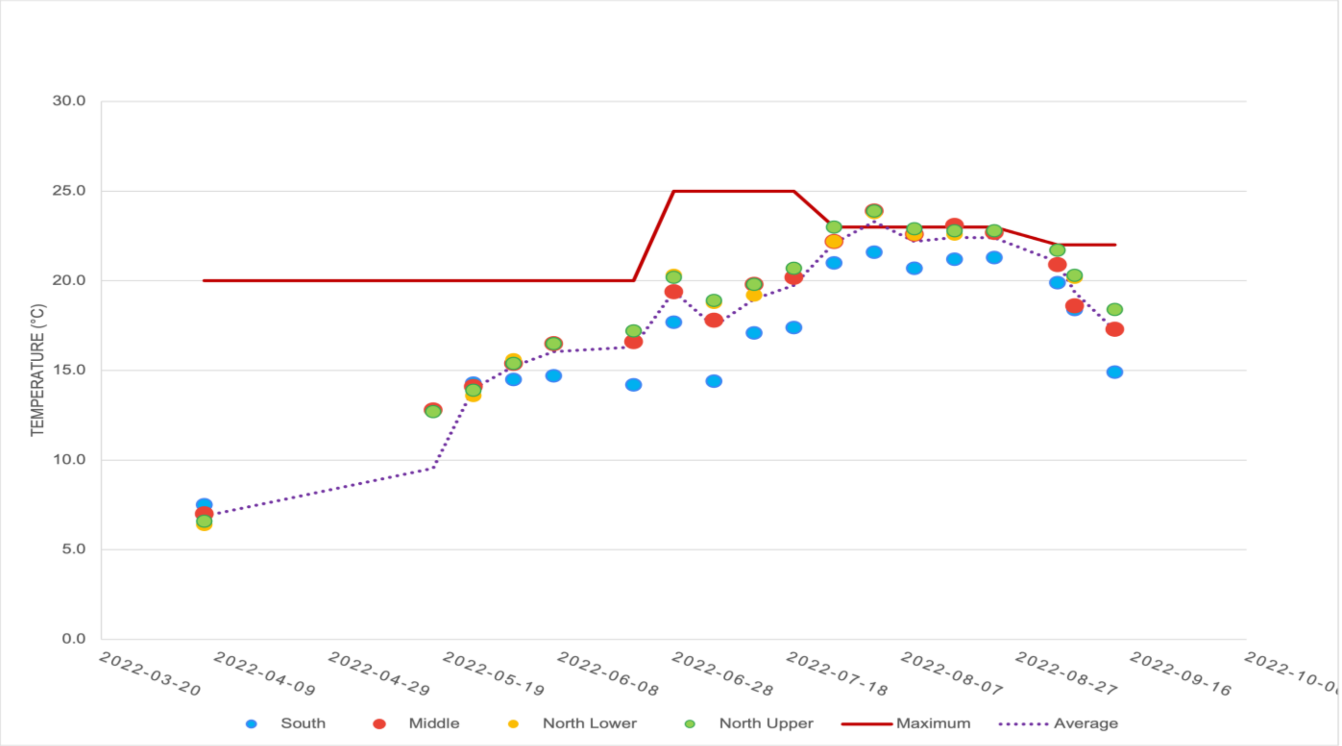


Figure 2a: Average Lake Windermere water temperatures are recorded weekly at the three sample sites from April 7th to September 13th, 2022.

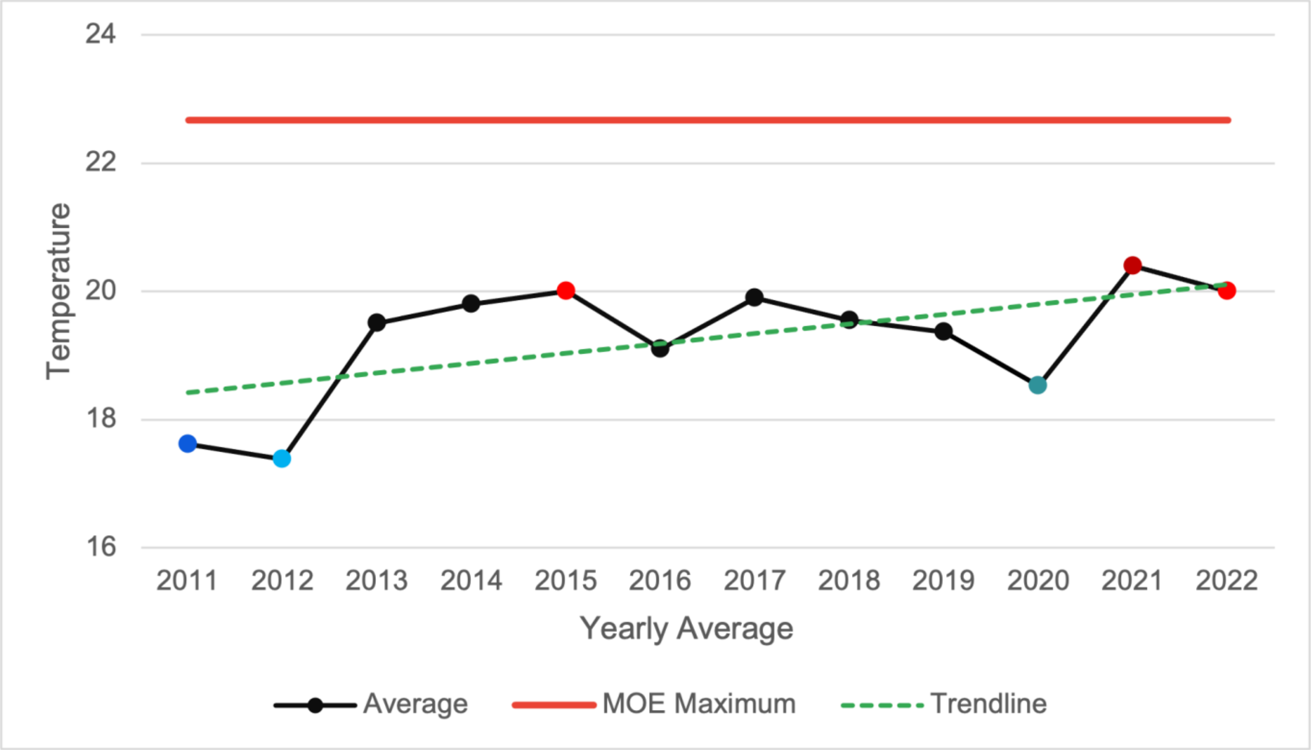
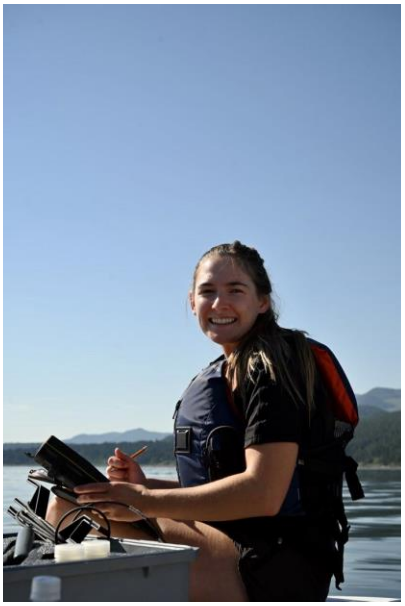


Figure 2b: Average Annual Water Temperature From 2011-2022.

2.2 Dissolved Oxygen

Overview

Dissolved Oxygen (DO) is another name for the free oxygen gas dissolved in water. Some amount of DO is required for almost all species of aquatic life to survive. However, too much or too little oxygen can harm aquatic life and negatively affect water quality (Ministry of Environment, 2017a).



Oxygen can be transferred to water from the atmosphere or produced by submerged aquatic plants and phytoplankton during photosynthesis. It is then removed from the water through respiration, chemical reactions, and organic decomposition in aquatic plants and animals. For example, a large amount of decomposing plant material within a lake can decrease DO concentrations in the water because oxygen is consumed during the decomposition process (Neufeld et al., 2010).

The capacity for water to hold dissolved oxygen is inversely related to water temperature. The inverse relationship between water temperature and dissolved oxygen means warmer water holds less oxygen than cooler water which holds more oxygen (Ministry of Environment, 2017a). Warmer waters also directly influence the rates of biogeochemical reactions and transformation processes within the water column and sediment bed. Temperatures increase metabolic rates, which affects BOD decay, sediment oxygen demand, nitrification, photosynthesis, respiration, and decreased dissolved oxygen levels (Harvey et al., 2011).

The MOE recommends that DO never drop below an instantaneous minimum of 5 mg/L. The guideline for an average of five samples taken over 30 days is 8 mg/L (Neufeld et al., 2010; Truelson, 1997). It is also recommended that DO not exceed a maximum of 15 mg/L to prevent adverse effects of toxicity (Neufeld et al., 2010).

Results

During the 2022 monitoring season, the average DO values of five sites over 30 days did not fall below the MOE 8 mg/L minimum threshold for an extended period, and they did not drop below the instantaneous minimum of 5 mg/L, nor did they exceed the 15 mg/L maximum recommended by MOE (Figure 3a).

The Instantaneous values ranged between a low of 6.3 mg/L recorded on June 21st at the North lower sample site and a high of 11.4 mg/L recorded on April 7th at the Middle sample site (Figure 3a). Although DO did not fall below the instantaneous minimum of 5 mg/L, it is essential to note it was recorded at an average of 6.5 mg/L across sample sites on June 21st, the same sample day when water temperatures dropped, and turbidity spiked (Figure 2a and Figure 4a).

An analysis was conducted on the correlation between water temperatures and DO, resulting in a negative (inverse) correlation of -0.72. (Figure 3b). This correlation between the increase in water temperatures at the end of July and the decrease in DO is significant and coincides with Figure 3c. This correlation could indicate that the initial decrease in DO is related to the initial increase in temperature. However, the DO was sustained below the minimum 8 mg/L average for an extended period, which could be related less to the immediate effects of temperature and more to temperature impacts on the rate of biogeochemical reactions and metabolic rates in the water column (Figure 3c). The most interesting point is that DO dropped prior to an increase in temperature (Figure 3b), and the lowest recorded DO was on the same day turbidity was at its highest. This pattern could indicate a more significant correlation between DO and turbidity compared to DO and temperature.

The highest DO values were recorded at the South sample site (Figure 3a). These high values may be due to the proximity to the Columbia wetlands, which have abundant aquatic plant life that photosynthesizes and contribute oxygen to the water. It may also be due to the slightly cooler temperatures of water flowing out of the wetlands, which hold more oxygen. The sample site with the highest DO readings is the North upper site. However, the middle samples site also saw some of the highest readings and even exceeded the North sample site on July 12th, which had a reading of 10 mg/L.

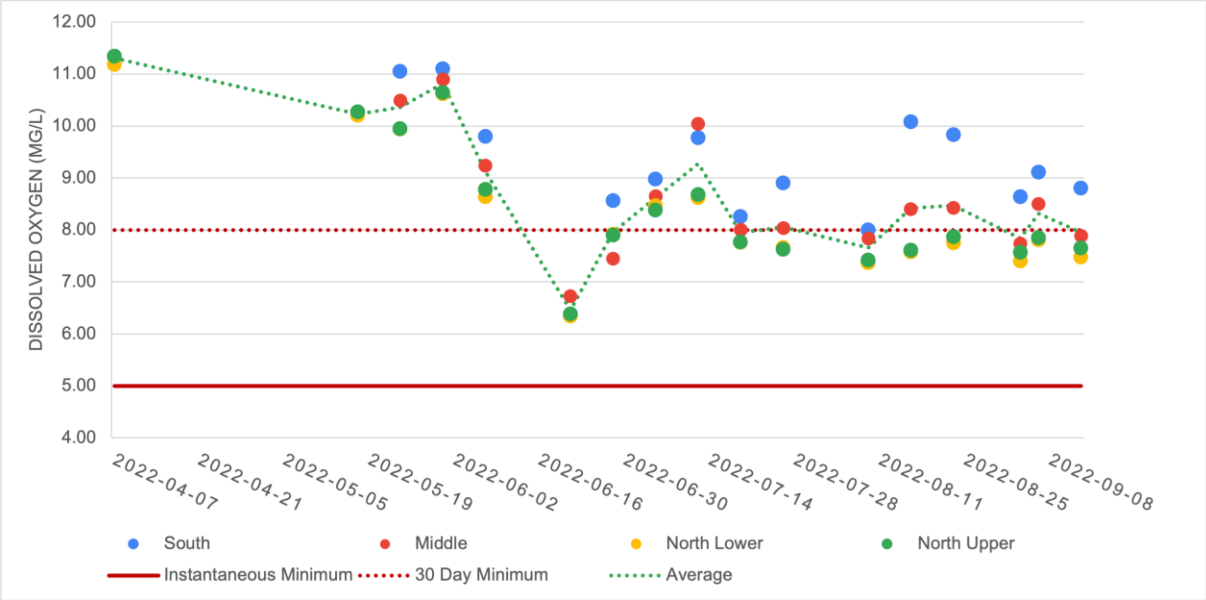


Figure 3a: Lake Windermere Dissolved Oxygen levels; instantaneous DO values, average DO over 30-days and all five sites, and MOE minimum allowable DO instantaneous and average values.

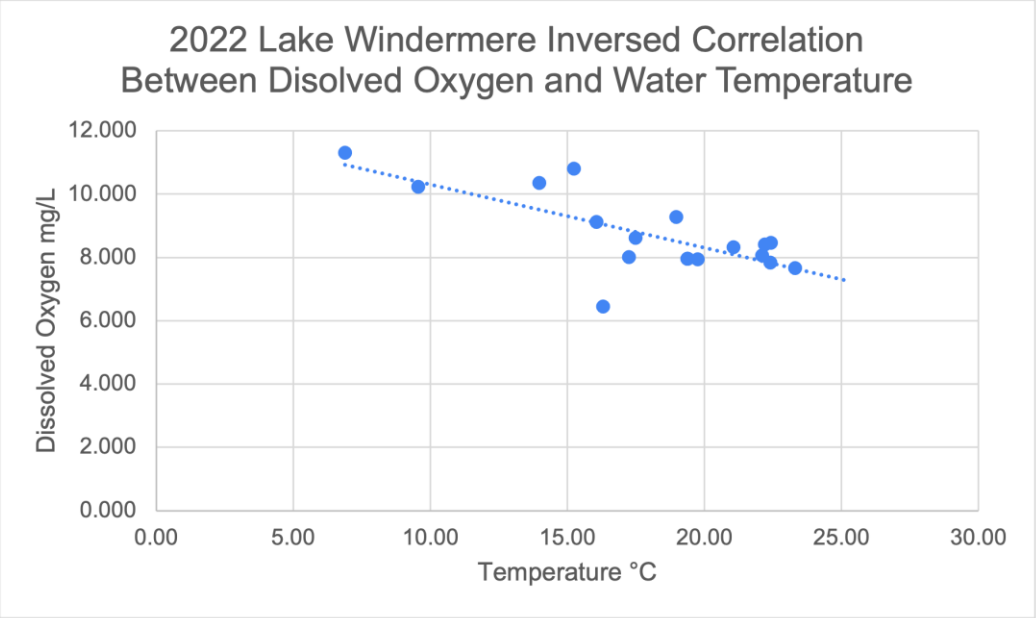


Figure 3b: Lake Windermere 2022 Inverse Correlation between Dissolved Oxygen and Water Temperature Averages.

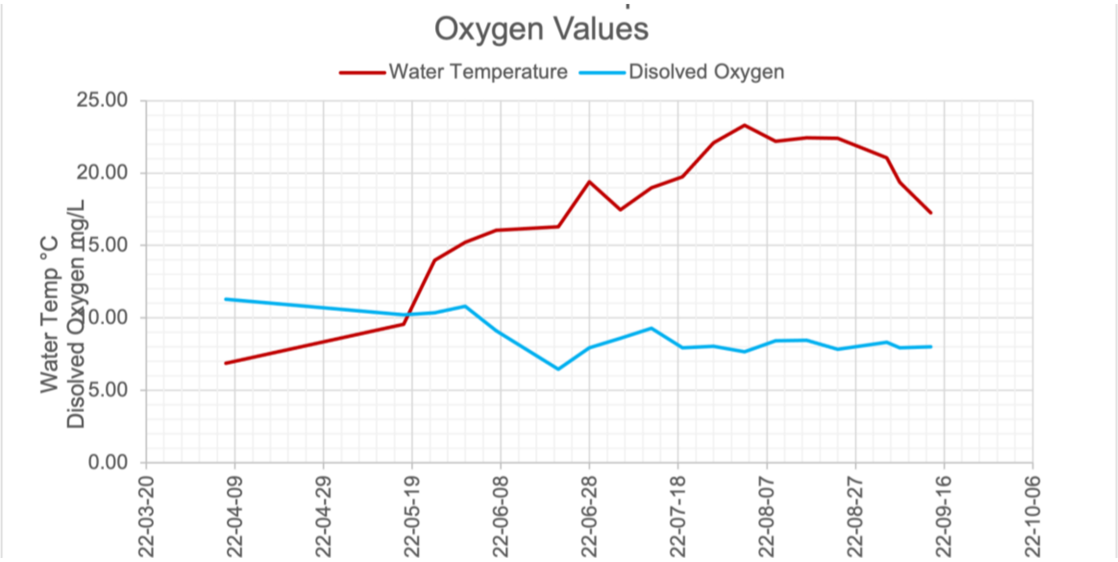


Figure 3c: Lake Windermere Water Temperature Average and Average Dissolved Oxygen.

2.3 Turbidity

Overview

Turbidity is a measure of the light scattered by particles suspended in water and indicates the clarity of the water. Suspended particles in the water consist of silt, clay, organics, algae, and other microorganisms. These particles may carry pathogens and chemicals harmful to human health and reduce light penetration, thus affecting primary and secondary productivity. When light cannot penetrate easily to reach aquatic plants, this reduces their rate of photosynthesis, reducing the amount of oxygen in the water. Fish can also become stressed due to reduced ability to navigate and find prey, clogging of gills, and other physiological stressors (Ministry of Environment, 2017a).

Since aquatic life in Lake Windermere has adapted to seasonal flushes of sediment into the lake, the acceptable amount of turbidity depends on the time of year. The most turbid waters typically occur during "freshet" (the spring runoff period) or after heavy rainfalls. The turbidity objectives for Lake Windermere are set to protect recreational water quality and aquatic life (Neufeld et al., 2010).

The turbid-flow period coincides with freshet and commences when the accumulated snowpack melts in the spring, increasing streamflow. It ends in the summer when the snow in the watershed has melted, flows return to normal and water levels are more stable. The turbid flow period occurs between May 1st to August 15th. The MOE turbid-flow maximum indicates that the 95th percentile of turbidity measurements taken in 5 days over 30 days should not exceed 5 NTU (turbidity units).

The clear-flow period is set between August 16th through April 30th. During this time, turbidity values tend to be very low, with any elevated values resulting from rain events and physical disturbances of stream banks. The MOE maximum turbidity at clear flow should be <5 NTU. The mean turbidity (based on a minimum of five weekly samples collected within 30 days) during the clear-flow (non-freshet) period should be <1 NTU.

Results

Turbidity in 2022 did exceed the acceptable ranges for recreational water quality and aquatic life, but only on three separate occasions at the South sample site (Figure 4a). The mean 30-day turbidity values for 2021 did exceed MOE recommendations for turbid flow on June 21st but only by 0.25 NTU at 5.25 (Figure 4a). The South sample site saw the highest peak in turbidity on June 21st at 14 NTU and the second-highest peak on July 5th at 5.81 NTU (Figure 4a). The 2022 turbidity peak was significantly lower than the peak turbidity of 2021, which was 22.7 NTU and occurred on June 6th at the South Site. June 21st was the start of freshet, as seen in the high turbidity reading, low water temperatures, and decrease in DO. This turbidity response is typical for many river systems during freshet because of the high volumes of meltwater runoff, which can erode lower-order stream channels and carry large amounts of sediment downstream.

Three instances were recorded during the turbid flow period where readings exceeded MOE objectives (Figure 4a). The highest three occurred during the turbid-flow period, from June 7th-28th and the remainder during the particular flow period. All the turbid-flow readings occurred at the South sample site, likely due to sediment entering the Columbia River through Dutch Creek and settling in Lake Windermere. As noted in the Dissolved Oxygen section, it is believed the changes in DO are more closely related to the turbidity values, as opposed to the temperature values. Wetlands usually help attenuate high turbidity by slowing flows and allowing sediment to settle; however, the sediment loads coming in through the wetlands in the 2021 freshet may have been too high for this to occur.

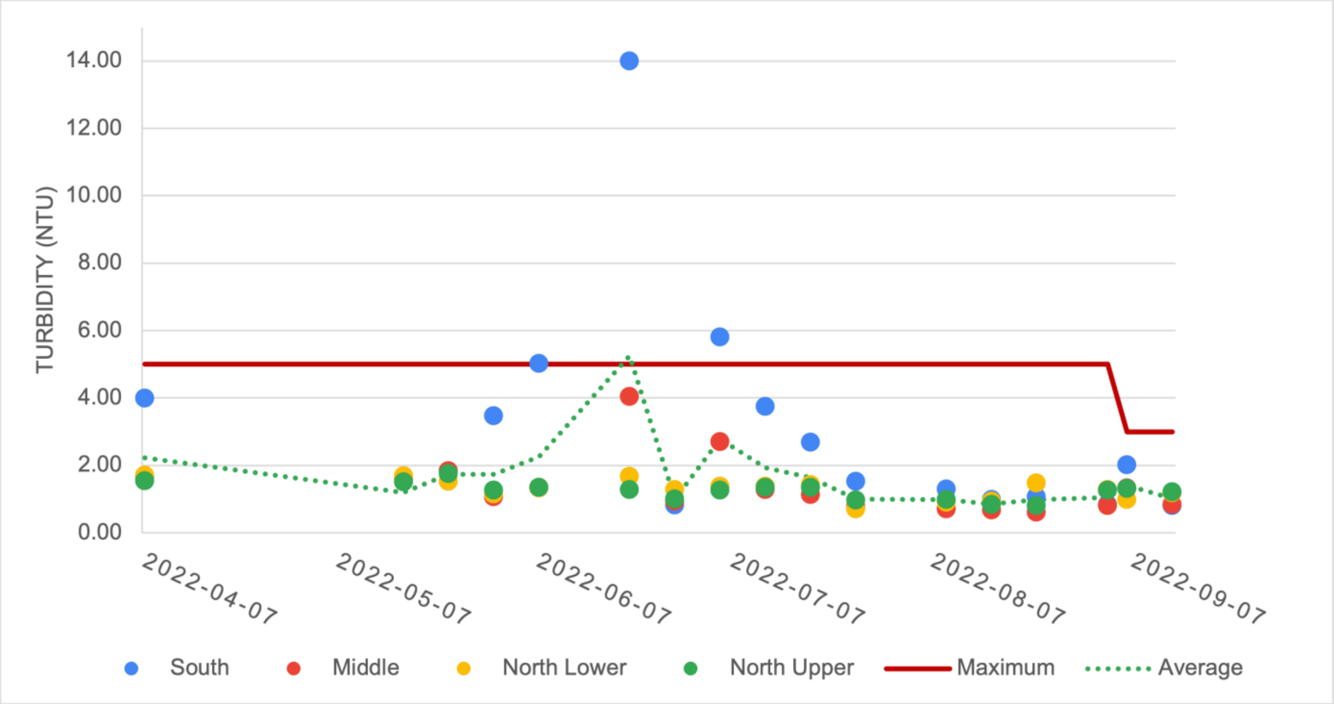


Figure 4a: Lake Windermere 2022 Turbidity (NTU) Levels; mean 30-day Turbidity, recommended maximums, and site-specific measurements.

2.4 pH

Overview

pH measures the free hydrogen ion concentration (H+). pH is reported on a scale from 0 to 14. Solutions with a pH between 0 and 7 represent an acidic environment, and solutions between 7 and 14 represent a basic or alkaline environment. pH is reported in logarithmic units, meaning a change in one unit of pH represents a ten-fold change in the actual pH of the solution. For instance, water with a pH of 4.5 is ten times more acidic than water with a pH of 5.5, while water with a pH of 3.5 is one hundred times more acidic than water with a pH of 5.5.

The pH of natural lakes is rarely neutral because of dissolved salts and carbonates, aquatic plants, and the mineral composition of the surrounding soils. pH can fluctuate daily as well as seasonally. Many aquatic species are sensitive to sudden changes in pH. However, most species have adapted to the natural pH fluctuations spread over time. If the pH of a lake changes dramatically within a short time frame, it could indicate a pollution event or some other form of disturbance.

The water in Lake Windermere consistently trends towards slightly alkaline (pH values around 8.5), characteristic of lakes fed by water flowing over limestone bedrock materials in the Canadian Rockies (BC Ministry of Health, 2007; Rollins, 2004). No MOE objective is set for pH in Lake Windermere; however, most aquatic organisms prefer a habitat where pH stays within 6.5-9.0 (Neufeld et al., 2010).

Results

pH measured in 2022 was comparable to measurements taken in 2021. The pH measurements for 2022 ranged from 7.4 to 8.47. pH measurements for 2021 were recorded to be between 7.9 and 8.8 (Figure 5a). There were no significant dramatic changes in pH during 2022. However, on July 12th, there was a minor drop to 7.40, specifically at the Southern Sampling site. The South sample site recorded the lowest pH throughout the entire season but did not get close to or fall below the MOE minimum of 6.5. The North Upper site recorded a season-high pH of 8.47 on September 6th, significantly lower than the 2021 seasonal high of 8.78.

There was no apparent correlation between the pH and the turbidity measurements during this season. The only real sign of any relationship is with the South sample site, which saw a severe pH drop followed by a spike and then a drop again. This pattern was delayed about a week from the same spike seen in the South sample site turbidity measurements (Figure 4a).

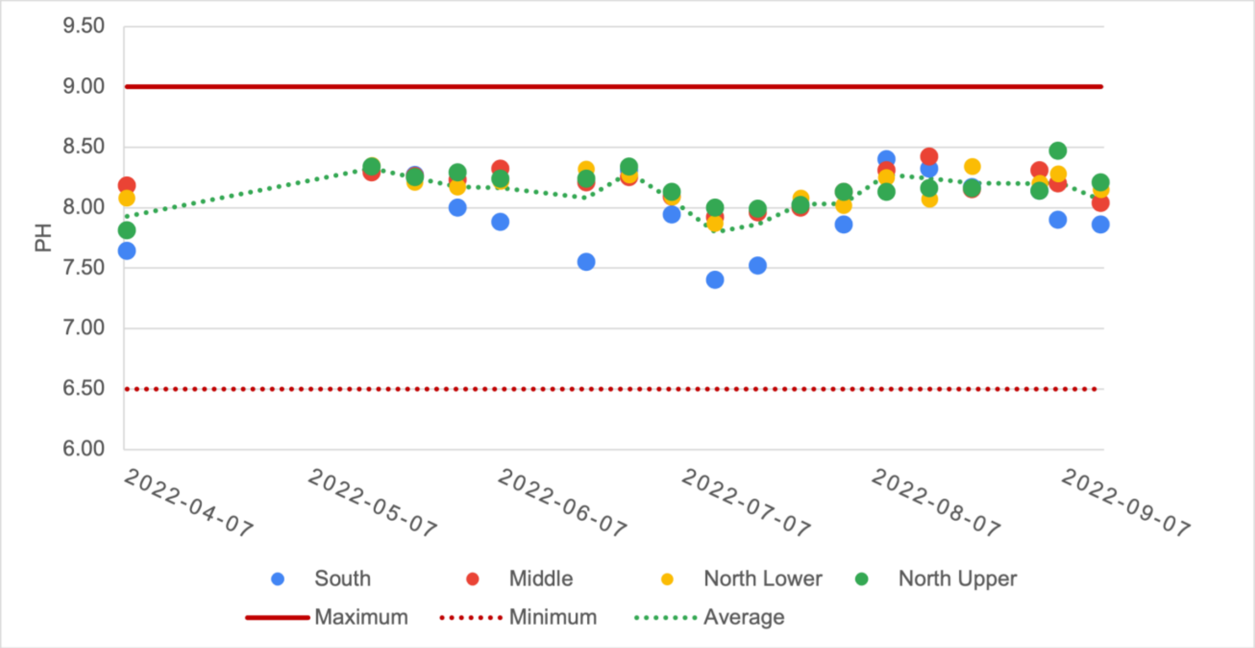


Figure 5a: Lake Windermere pH recordings, 2022. Maximum and minimum MOE requirements.

2.5 Specific Conductivity

Overview

Specific Conductivity measures the ability of water to conduct an electrical current. It is affected by the presence and mobility of ions in the water. Conductive ions include dissolved salts and inorganic compounds like chlorides, sulphides, and carbonates. For this reason, a measure of Conductivity in water may be used as an indicator of water pollution.

Water conductivity is directly related to water temperature; the warmer the water, the faster the mobility of the ions, and so the higher the Conductivity (Behar, 1997). Specific Conductivity is reported at a standard temperature (20°C). Water's specific conductivity is also affected by the bedrock geology of the surrounding area. The Lake Windermere watershed is surrounded by weathering-prone bedrock (such as limestone or clay), giving higher conductivity values than more stable bedrock (such as granite). The effects of water temperature on Specific Conductivity are corrected when using the device.

Results

The results of Specific Conductivity in Lake Windermere ranged between 170.8 µS/cm to 692.5 µS/cm in 2022 (Figure 6a). The average of all sample sites exceeded the maximum for the first five weeks and exceeded the maximum again on August 16th. These measurements exceeded the 2021 data. All Sample sites exceeded the MOE maximum the first week, and the Middle and North sites exceeded the MOE maximum for the first five consecutive sample weeks from April 7th – June 7th. The sample site with the lowest Specific conductivity was the South sample site, near the outlet of the southern wetland.

The South site recorded the lowest measurements throughout the summer. On June 21st, the lowest Specific conductivity was recorded at 166.7µS/cm, almost below the MOE minimum objective of 150µS/cm. An interesting point of note is that the South sample site had the lowest conductivity throughout the season and the highest turbidity throughout the season. This relationship was particularly evident on June 21st, when the Specific Conductivity reading was the lowest and the same day that turbidity was the highest. August 16th recorded the highest reading at the North lower site, at 692.5 µS/cm. There were no other readings that were this high at the same time. Even the northern upper site recorded a reading of 231.9 µS/cm, which is significantly lower. There were no other unusual readings on this day for any other parameter, such as turbidity or pH. Therefore, it is possible that this reading was inaccurate due to equipment malfunction or that the reading was taken improperly, such as by dropping it too low into the water.

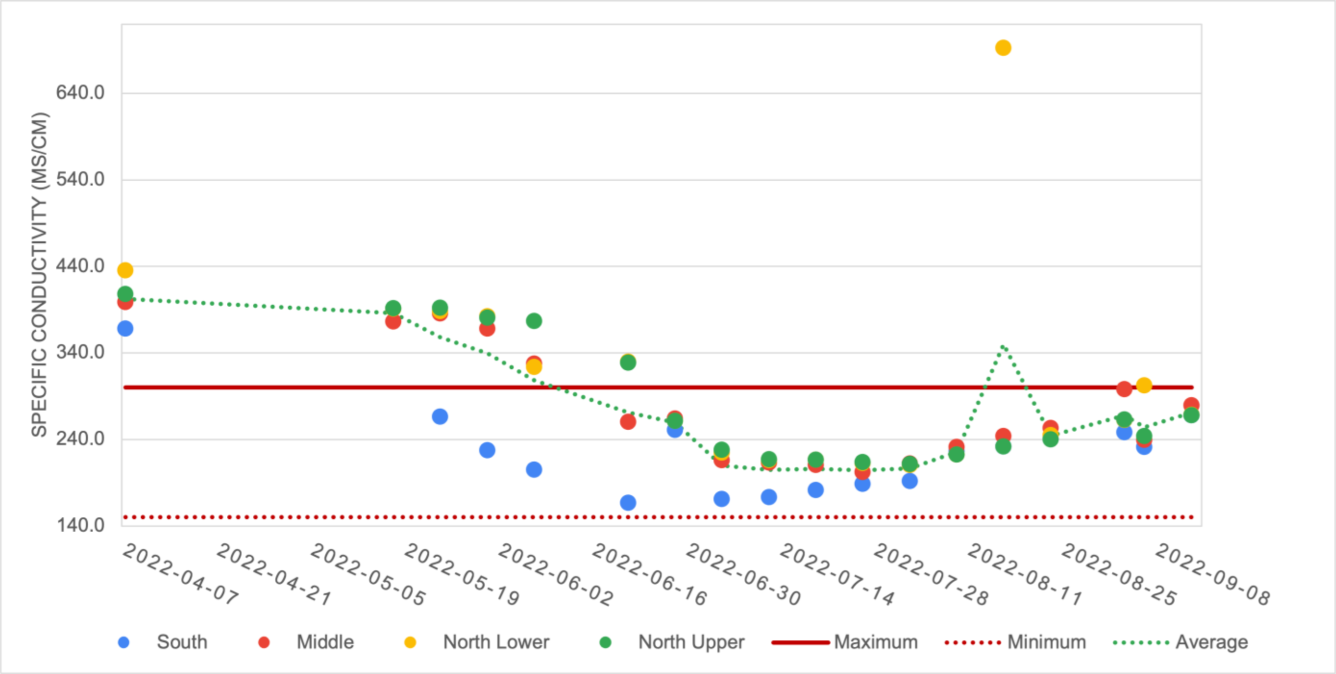


Figure 6a: Lake Windermere Specific conductivity (µS/cm) measurements 2022. Recommended maximum and minimum values and average conductivity across all sample sites.

2.6 Phosphorus

Overview

Phosphorus (P) is a nutrient essential for life. Phosphorus is used by plants and aquatic animals for processes involved in photosynthesis and metabolism. When present in low quantities, this nutrient can limit the growth of aquatic life. When present in high quantities, it can lead to excessive algal and aquatic plant growth and overproduction of bacteria, affecting other aquatic life and human health through toxic algal blooms.

Phosphorus exists in two primary forms in water: dissolved and particulate. Dissolved Phosphorus is more readily available to algae and aquatic plants for growth and photosynthesis (US EPA, 2012). Particulate Phosphorus is attached to particles in the water and is not always available to aquatic plants or animals. "Total P" is a combined measurement of the dissolved and particulate forms. Total P is often the parameter monitored during water quality objective studies.

Phosphorus is naturally derived from soil erosion and biological recycling within the lake. For example, natural sources of Phosphorus include nutrient cycling when plants and animals die and decompose and soil mineral transport. Two primary human-caused inputs of Phosphorus into waterways in North America include agricultural runoff and wastewater. Within the Lake Windermere watershed, possible anthropogenic sources of Phosphorus in the tributaries and the lake include agricultural runoff, golf course and resort fertilizer runoff, waterfront lawn & garden fertilizer runoff, and municipal stormwater runoff containing detergents and other phosphate-bearing chemicals, or leaky shoreline septic systems.

Historic sampling results indicate that Lake Windermere is "oligotrophic." An oligotrophic lake means there are low nutrient levels, clear waters are expected, and the total phosphorous often limits the growth of aquatic life. The Ministry of Environment (MOE) recommends that the Total Phosphorus in Lake Windermere not exceed a concentration of 10µg/L (0.01 mg/L) to protect drinking water sources and aquatic life. As recently as 2015, however, the LWA found that water samples after ice-off significantly exceeded the MOE recommendations for total phosphorous concentrations in Lake Windermere.

Results

2022 saw a slight decrease in results for total and dissolved P levels compared to 2021. The highest recorded value for Total P in 2022 was 19.3µg/L at the North Upper sample site on June 26th, (there were no other unusual readings on this day for any other parameter, such as turbidity. Therefore, it is possible that this reading was inaccurate due to equipment malfunction or that the reading was taken improperly, such as by dropping it too low into the water) compared to the highest recorded value for Total P in 2021, which was 29.70µg/L at the Middle sample site on June 22nd. The lowest value in 2022 was 6.12µg/L on August 23rd at the North Upper sample site, and the lowest value in 2021 was 5.60µg/L on September 14th at the Middle sample site (Figure 7a). Of the total P samples taken in 2022, 38% exceeded the MOE recommendation of 10µg/L. 75% of samples at the North Lower sample site exceeded the MOE maximum, while average total P exceeded the MOE Maximum for 50% of the sample days during April and July, and July had the highest average Total P, recorded at 11.75µg/L.

At the Middle sample site, the highest ever-recorded value of total P by the LWA was 67 µg/L on August 20th, 2013. This record was more than six times the recommended limit and prompted the LWA to increase monitoring for phosphorous. Since then, 37 out of 165 samples (23%) have exceeded the total phosphorus recommendations, six of which occurred in 2022 (Figure 7b).

It is expected that Total Phosphorous be higher when Turbidity is highest. Like last year, there was about a two-week delay between an increase in Turbidity and an increase in total P. This relationship occurred in the 2022 Sampling Season, when total phosphorous was highest on July 26th and Turbidity was highest prior to June 21st, which was the same time frame observed in the 2021 data. This also indicates that the sources of phosphorous in the Lake Windermere system fluctuate throughout the season. It is not easy to point to the source of phosphorous as it occurs both naturally and through human inputs. It is essential to continue to watch this trend for future management strategies.

Figure 7a: Monthly Total Phosphorus and Monthly Average Total Phosphorous, collected from Lake Windermere between April 7th and August 23rd, 2022.

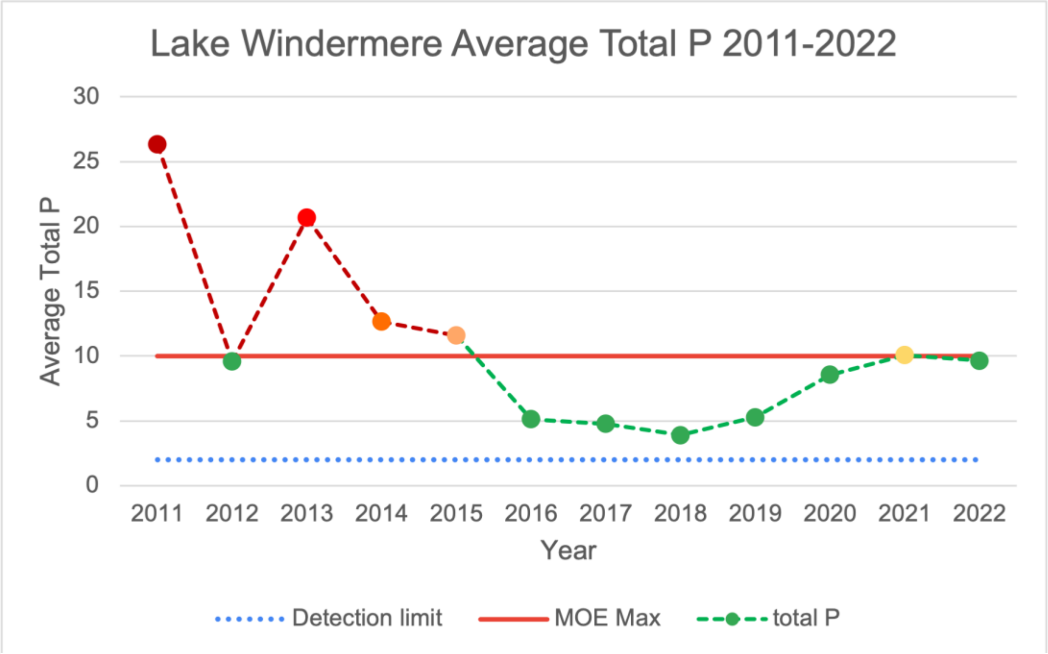


Figure 8b: Lake Windermere Average Annual Total Phosphorous data, 2011-2022.

2.7 Secchi Depth

Overview

Secchi depth is related to water clarity and measures how deep light can penetrate the water column. Changes in water clarity, like turbidity, can result from the suspended particles in the water. These suspended particles can combine zooplankton, phytoplankton, algae, pollutants, or sediment (clay and silt). Clear water lets a beam of light penetrate more deeply into the lake than murky water. Sunlight is needed for aquatic plants to photosynthesize and for phytoplankton to grow and reproduce (Ministry of Environment, 2017a). Therefore, Secchi measures how deep the photosynthetic zone goes into the water column.

Secchi data collected year after year can provide information about trends in water clarity. Secchi depth generally follows the inverse pattern of turbidity. When turbidity is high, the Secchi depth is low because it is difficult to see deep into the water. There are no objectives for Secchi depth in Lake Windermere (Neufeld et al., 2010). Following the objectives for turbidity, we should expect the Secchi depth to be lower in the spring during freshet and higher in the summer as the lake flushes out over time.

Results

The average Secchi depth in 2022 across all sample sites was 3.51m, which is 1.69m deeper than the average 2021 depth of 1.82m. Secchi depth was the lowest on June 21st at an average of 2.85m and remained low until the end of July. This indicates the timing of spring freshet when the snow melts. The 2022 lowest average readings correspond with a simultaneous increase in turbidity. However, there was a spike in average turbidity on July 5th, which did correspond with a decrease in average Secchi depth (Figure 8b). Secchi depths were lowest in the South sample site because this site is the site closest to the tributary from Columbia Lake.

Comparing Secchi depth to Total depth creates a more accurate picture of the water column's clarity (Figure 8b). If the Secchi depth is the same as the total depth, we can see the bottom of the lake. The Secchi depth was the same as the total depth for only 30% of the data in 2022 (Figure 8b). The North site, the deepest site, had the most Secchi depth readings that were less than the total depth. The middle site had 61% of its Secchi depth readings, the same as the total depth. On June 21st, all sites recorded the largest variance between Secchi depth and the maximum depth. This also correlates to when the average Secchi depth was the lowest and when the turbidity was the highest (Figure 8b).

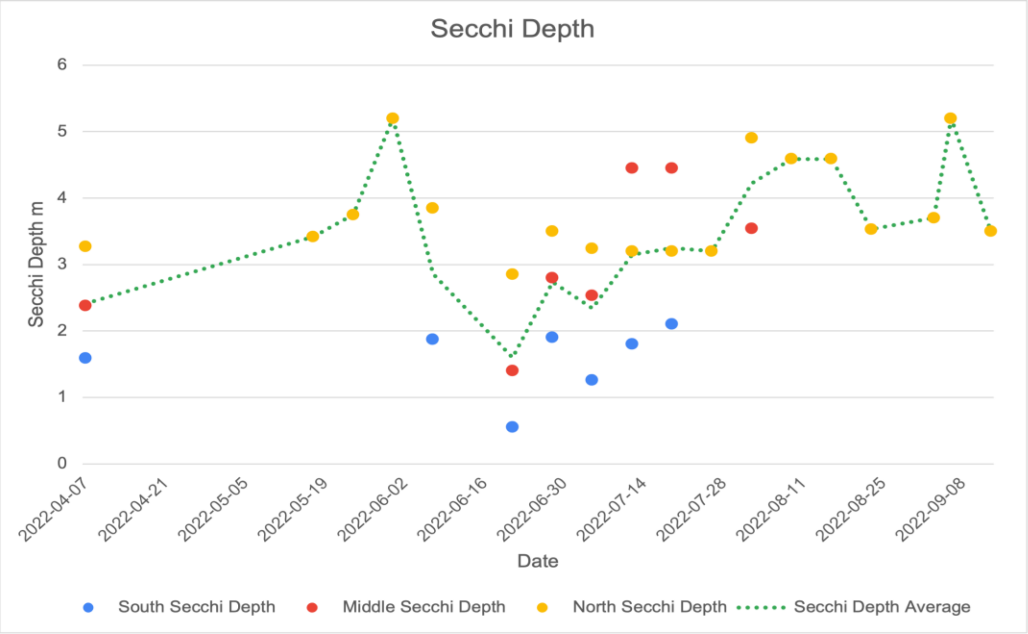


Figure 2a: Lake Windermere Secchi depth (metres) measured weekly for the sampling period April 7th to September 13th, 2022. Secchi depths the same depth as the water column were not included.

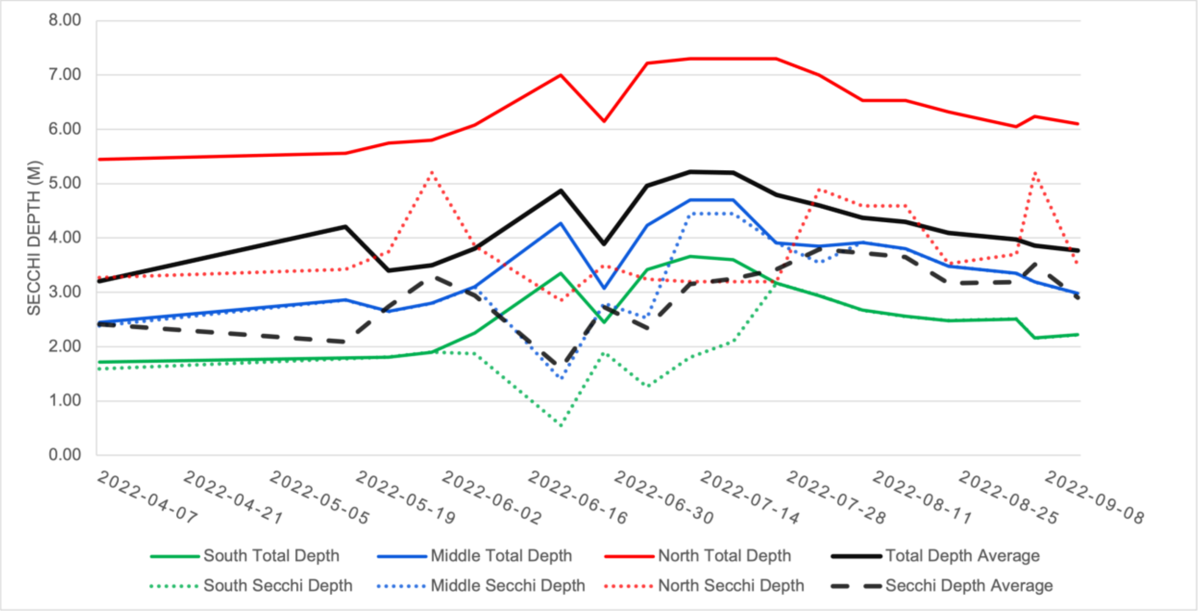


Figure 8b: Lake Windermere Maximum Secchi Depth and Maximum Total Lake Depth in 2022.

2.8 Total Depth

Overview

Lake Windermere is a widening of the central Columbia River channel, which makes it different from typical lakes around Southern BC. The main difference is that it is very shallow, on average, between 3-4m depth in mid-summer. It also has a high-water exchange rate (flushing) which allows water to flow through more quickly than an average lake, giving it a better capacity to carry sediments and nutrients downstream because of this faster flow.

The average water depth is recorded for all three sample sites throughout the lake, but this is not representative of Lake Windermere. This lack of representation is because the South end, where water flows in from the Columbia Wetlands, tends to be much shallower than the other two sites. The North sample site is the deepest point in the lake, measuring on average between 6-7m in depth.

The process of water becoming separated into lighter and denser layers is called "thermal stratification." The water will separate into layers in deeper lakes, with cooler, denser water falling to the bottom. Lake Windermere does not stratify, meaning there is no significant difference between the North Upper and North Lower water quality samples.

Depth can be essential for aquatic life, recreational boaters, and drinking water users. Shallow water poses more risks to boaters because they can more easily be caught on sediment bars or clog their motors with aquatic vegetation growing up from the bottom of the lake. Shallower water also warms up more quickly, posing issues for drinking water quality and aquatic life's survival. There is no objective set for lake depth in Lake Windermere, but levels below 2m generally cause concern.

Results

Lake depth in 2022 followed a slightly unexpected trend than in previous years. Usually, it is higher in spring during freshet and gradually declines through the late summer due to less input from snowmelt runoff/precipitation and increased evaporation effects. Instead, 2022 saw a delayed increase in depth, where it peaked in late June and remained high throughout July and even into August. This trend, and annual average depth, was more significant than in previous years due to a deep snowpack winter and increased precipitation throughout the spring.

The 2022 season had one of the deepest average water depths ever recorded (4.3 m) since depth monitoring began in 2013. The only season with an average water depth deeper was in 2013 at 4.4 m. The difference between these two seasons was that in 2013 all the monthly averages were high, whereas in 2022, June was low, and in July, August saw high waters compared to previous years. Over the season, 2022 saw a sharp incline between June and July and a gradual decline between the end of July and August (Figure 9a). This variability was likely caused by abnormally deep snowpack and unusual spring weather patterns, such as increased precipitation in June and cool temperatures, causing a delay of snow melt into the lake. The changes in water depth are more accurately depicted in Figure 9b, which shows the average monthly depths. Figure 9b shows that July had some of the deepest water depths ever recorded; in June, the average water depth was one of the shallowest ever recorded. The Average water depth in August was also one of the deepest on record (Figure 9b).

The highest seasonal depth was 7.3m and was maintained for three weeks from July 12-28th at the North sample site. This depth is the same as the highest ever recorded values at this site since monitoring began in 2006, which was also 7.3m, recorded in July 2012 and June 2013. The 2022 depth is higher than the deepest value in 2021 at 7.1m on June 30th (Figure 9b). The 2022 season saw a gradual decline in average water depth, where after its peak on July 12th, the water depth dropped 1.5m over the remaining two months.

Interestingly, there was a peak in water depths on the 21st, which is thought to be the start of freshet. Compared to Secchi depth, there is an increase in Secchi depth at this time, indicating an increase in water clarity. However, there is a 1m drop in depth across all sample sites during the following week of sampling. This unusual pattern occurred across all sample sites, which leads us to wonder whether it was user error during data collection, such as a windy day when the boats were blown around, or if there was a 2m change in depth over two weeks. There was a severe drop in Turbidity on June 28th, where the South sample site went from 14 NTU to 0.82 NTU and the average Turbidity went from its peak at 5.25-1.01 NTU in one week. Temperature also saw a severe spike between June 21-July 5th, from 16.3°C to 19.4°C to 17.5°C. Even though it is unlikely the depth would drop in one week and then spike up again, this pattern is consistent with the temperature and turbidity readings. Given the preliminary information, it is unclear what this information could indicate. It is suspected that a second purge of the tributaries on July 5th followed a severe warm, dry spell on June 28th. It is unclear whether this was from the hot weather causing snow melting or a precipitation event.

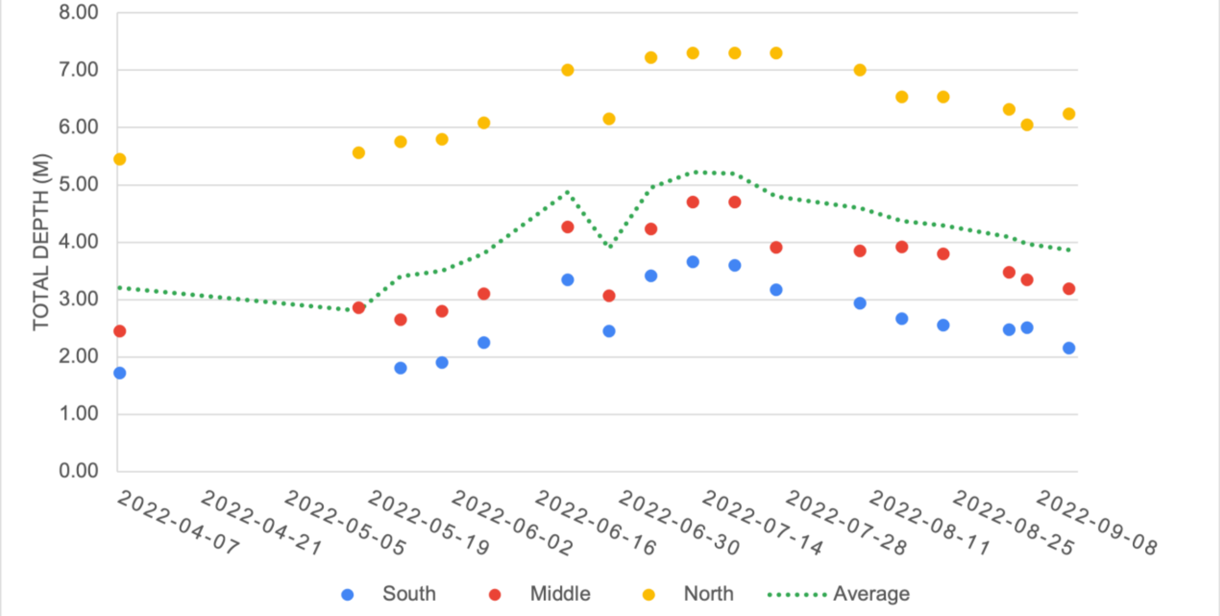


Figure 9a: Lake Windermere Total Depth (m) of different survey sites and depth-averaged across all sites, measured between April 7th and September 13th, 2022.

Figure 9c: Average Annual Depth Comparing Data from 2013-2022.

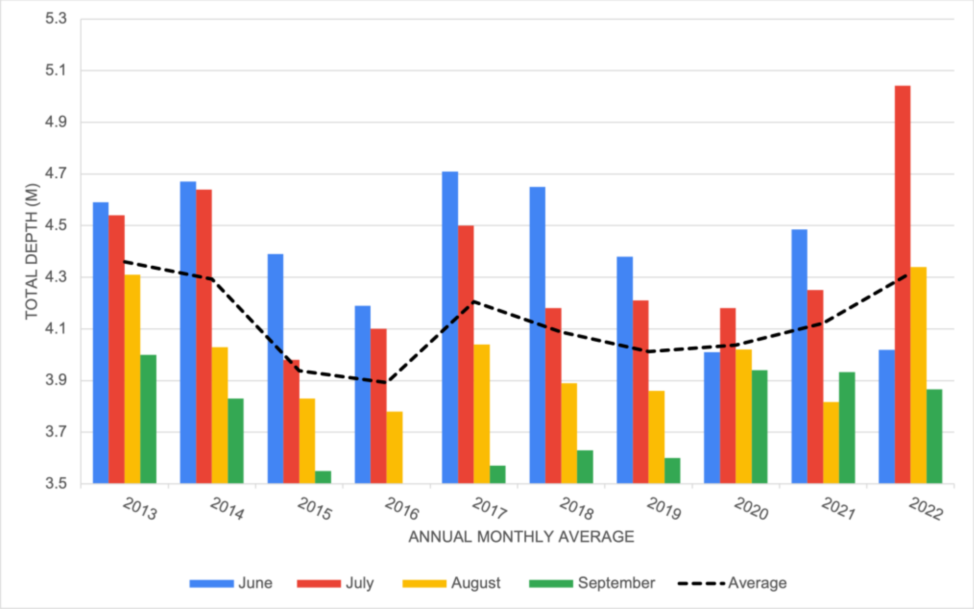


Figure 3b: Average Monthly Water Depths from 2013-2022

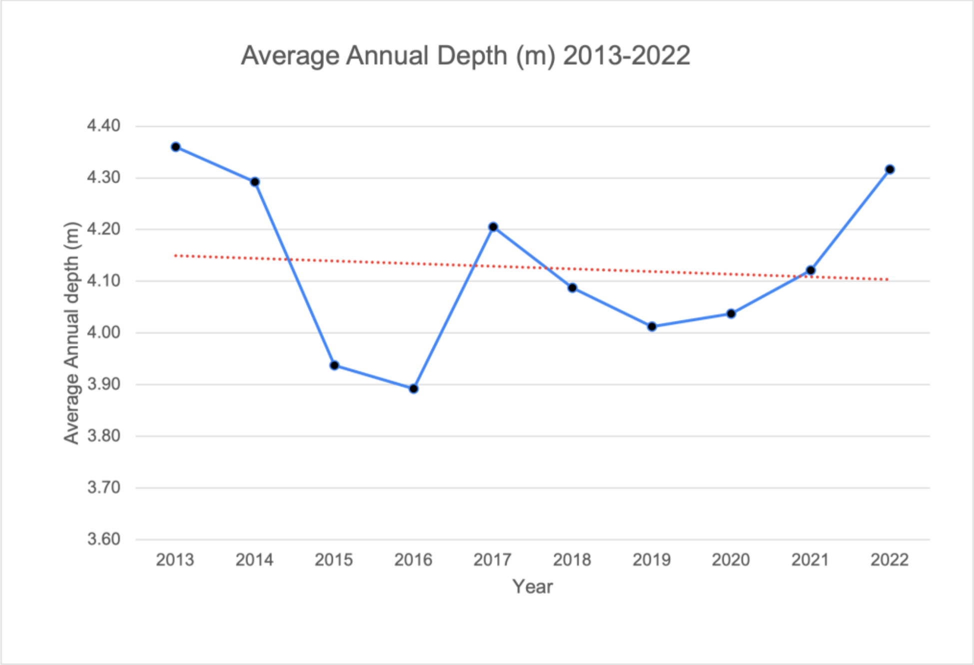


Figure 9c: Trendline of Changes in Average Annual Water Depths from 2013-2022.

3. Waterbirds

Overview

In 2018, LWA conducted their first Waterbird Survey, with a report highlighting the findings. This project was taken to learn more about the bird populations using Lake Windermere. It was found that Lake Windermere provides significant bird habitat for large migrant flocks and breeding birds (Darvill, 2018). The lake is significant for large flocks of migratory birds, such as American coots (*Fulica americana*) and four grebe species- three considered at-risk species (Darvill, 2018). The LWA and Goldeneye Ecological Services undertook a boat survey in September 2020 and 2021-2022 to continue learning about bird populations on Lake Windermere.

Results

During the Survey on October 5th, 2022, 953 individuals were recorded from a total of 19 different species. Of these sightings, the Surf Scoter and Red-necked Grebe, Horned Grebe, Eared Grebe, Western Grebe, and California Gulls have been designated species at risk. Of the 953 individual sightings, 23 or 2% of all individuals are Species at Risk. There is a strong recommendation for management strategies to accommodate human use and bird conservation for Lake Windermere.

Overall, much lower numbers of birds were recorded compared to the 2673 total individuals observed in 2021, which is a decline of 37%. One of the most significant declines in individuals was a decrease in coots and grebes compared to the previous three years. The total number of coots in 2022 was 152 compared to 1850 observed in 2021. The total number of grebes were 48 in 2022, compared to the 217 individuals observed in 2021. It could be due to extended warm weather and birds delaying migration. Observations during the survey include mixed flocks seen in the distance in Columbia Wetlands Water Management Area at the South end of the lake.

Rare observations for this survey were the at-risk Surf Scoters 17 and, as always, the high number of Red-necked Grebes on Lake Windermere. The at-risk species identified on Oct 6, 2022, include Surf Scoter 17, Horned Grebe 2, Western Grebe 1, and California Gulls at least 2. These species are seen each year during the October waterbird surveys.

Recommendations and Discussion

- Undertaking additional breeding season and fall migratory bird studies for Lake Windermere
- Factoring waterbird and wetland conservation into land-use decisions for Lake Windermere
- Improving signage about motorized boating regulations in the Columbia Wetlands WMA

- Improving public education about the use of eBird and the importance of conserving habitat values of Lake Windermere for migratory and at-risk bird species

4. Swim Beach Water Quality

Overview

Escherichia coli (*E. coli*) is a type of fecal coliform bacteria found in the intestines of most healthy warm-blooded animals. Most *E. coli* are harmless, though some can produce toxins that cause illness. *E. coli* in water can indicate sewage or animal waste contamination. Other coliform bacteria are commonly found in soil or vegetation and are part of the natural microbial flora.

The count of *E. coli* colonies per 100mL of water is a common way to measure how many of these species of bacteria are present in the water. However, it is essential to know that this value represents a total count of all *E. coli* colonies, which means it does not necessarily contain the strains which produce toxins harmful to humans. A higher *E. coli* count increases the probability that the water could contain a toxin-producing strain.

An *E. coli* assessment determines whether swim beach water quality meets recognized health standards. The LWA has an ongoing agreement with the Interior Health Authority (IHA) to collect public beach water samples; the IHA laboratory analyzes samples for *E. coli* bacteria in compliance with Health Canada Guidelines. Samples are collected at three public beaches around the lake: James Chabot Provincial Park (Athalmer), Kinsmen Beach (Invermere), and Windermere Beach (Windermere).

The Health Canada Guidelines for recreational water used for "primary contact" activities (e.g., swimming):

- Geometric Mean Concentration (minimum of five samples taken over 30 days): ≤200 *E. coli*/100mL
- Single Sample Maximum Concentration: ≤400 *E. coli*/100mL

Results

James Chabot public beach exceeded the 30-day Health Canada recommended limit of 200 colonies, with a reading of 350.93 colonies of *E. coli*/100mL. On July 11th the James Chabot's central site also exceeded Health Canada's individual sample limit of 400 colonies with a reading of 5100 colonies of *E. coli*/100mL.

For Lake Windermere, the average seasonal values were as follows:

- James Chabot Provincial Park 350.93 *E. coli*/100 mL
- Kinsmen Beach 13.58 *E. coli*/100 mL
- Windermere Beach 7.47 *E. coli*/100 mL

The highest single sample in 2022 was 5100 colonies of *E. coli* /100mL, recorded on July 11th at the Central site of James Chabot Beach. It's important to note that the east site was also high with 140 colonies *of E. coli* /100mL. This was the highest ever recorded *E. coli* value for Lake Windermere and the cause for the increase remains unknown. However, due to the following week having low readings of 1.5

colonies of *E. coli* /100mL, it is suspected this was a point source incident, caused either from animal or human feces immediately present in the area during sampling.

Results of swim beach sampling is updated throughout the summer season and can be found by searching for Kinsmen, James Chabot, or Windermere beaches at

https://services.interiorhealth.ca/publichealthprotection/watersamples.aspx

5. Tributary inflow - Windermere and Abel Creek

Overview

Besides the central Columbia River channel, Windermere Creek is the primary source of inflow into Lake Windermere. This tributary stream drains an area of approximately 90 km and provides essential fish spawning habitat (NHC, 2013). At the same time, Abel Creek is a much smaller tributary than Windermere Creek. Monitoring efforts are made as Abel Creek runs into Lake Windermere from the Paddy Ryan Lakes Reservoir used by the District of Invermere.

From 2007 to 2018, the Columbia Basin Water Quality Monitoring Program (CBWQM) ran on Windermere Creek. This project oversaw scientific data collection in East and West Kootenay streams through the fieldwork undertaken by local volunteers and non-profit organizations. LWA has continued monitoring Windermere Creek and now monitors Abel Creek as a continuation of this project.

Water chemistry follows similar protocols and uses the same equipment as lake water quality monitoring, with data collected for dissolved oxygen, specific conductivity, pH, Turbidity, and temperature.

Flow/velocity measurements are crude and taken using a meter stick to obtain surface velocity based on the principle of conversion of kinetic to potential energy. This measurement method overestimates average channel flow but underestimates actual surface flow due to friction. While not exact, if measured carefully and repeated the same way each time, this measurement can give us a general idea of how flow volumes change seasonally within a given stream area. During equipment comparisons between LWA and Shuswap Indian Band in October 2020, there was a significant discrepancy between the flow/velocity measurements using a velocity head rod vs. the flow meter method. In 2018, the LWA obtained four HOBO U20-L Water Level Loggers.

These loggers measure water temperature and pressure to provide a reading on flow measurements to complement surface velocity measurements. In September 2018, the first logger was installed in a stilling well in Windermere Creek; the second was installed in April 2019 in Abel Creek. The third will be installed on the Athalmer Bridge at the outflow of the Columbia River from Lake Windermere. The fourth is used as an atmospheric pressure gauge at the LWA Office.

Results

The sampling results from the 2022 Creek Surveys will be provided in a supplementary report.

6. Acknowledgements

The 2022 Lake Windermere community-based water quality-monitoring project was made possible thanks to generous funding support from:

- District of Invermere
- Reginal District of East Kootenay
- Columbia Basin Trust
- Columbia Valley Community Foundation
- Columbia Valley Local Conservation Fund
- Totem Charitable Foundation
- TD Friends of Environment Foundation
- BC Conservation and Biodiversity Awards
- BC Community Gaming Grants
- Canada Summer Jobs
- Eco Canada
- BC Parks
- BC Hydro
- Community Donations

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- Community volunteer Gavin Jacobs provided additional in-kind support as our volunteer boat captain
- The Interior Health Authority for swim beach samples.
- We would like to thank all our citizen scientist volunteers and collaborative groups who helped us with our 2022 sampling season!

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Appendix A

Sampling methodology

Water Quality

Lake Windermere is sampled following the BC Ministry of Environment Water Quality Assessment and Objectives for Lake Windermere (Neufeld et al. 2010). Water quality laboratory analysis was completed by CARO Analytical (Kelowna, BC). The following water quality data were collected at all three sample sites:

a) Weekly (May -September) -in situ (field measured) data including depth, Secchi depth, water temperature, specific conductivity, pH, dissolved oxygen (DO), and turbidity
b) Monthly (April -September) -Total Phosphorous and Total Dissolved Phosphorous

Water sampling took place within a four-hour timeframe on Tuesday mornings, from May to September 2021. Volunteer citizen scientists were joined by at least one trained LWA staff member for all lake excursions and assisted with field data collection.

Lake Sample sites were first located by boat using a hand-held Garmin eTrex20 GPS with the preprogrammed coordinates that align with the sample sites in ***Figure 1.*** Once at a sample site, depth and Secchi depth measurements were taken using a weighted Secchi disk and meter line. Water temperature, Dissolved oxygen and conductivity were read using a YSI ProDSS meter. pH is read using a Eutech Waterproof pH Test 10. Turbidity was read using a Hach 2100QPortable Turbidimeter calibrated to 10 NTU.

The North site was sampled at two depths (Upper and Lower) since this is the deepest part of the lake. The Upper water sample was collected at approximately 1m below the surface. The Lower water sample depth depended on the total depth of the water column: If the total depth was less than 5m then the Lower water sample was collected 1m above the lake bottom, but if the total depth was greater than 5m then the water sample was collected at 4m (due to the maximum length of the YSI. The Middle and South sites were sampled at 1m below the surface only. All water samples were collected using a horizontal VanDorn sampler.

When monthly phosphorous samples were collected, a cooler containing sample bottles was brought on board the boat. Water samples were collected into bottles, which were then kept on ice while being shipped via ACE Courier to CARO laboratories in Kelowna for analysis.

Aquatic Invasive Plants Survey

Please see Darvill (2022)

Water birds

Please see Darvill (2022)

Swim Beaches

Bacteriology samples were collected on Mondays between June and early September (excluding long weekend holidays) before 1:00pm from three public beaches {Windermere (3 site), James Chabot (3 sites), and Kinsmen (3 sites)}. Sample bottles were filled using a triple-rinsed beaker dipped inverted below the water's surface then turned upright within the middle of the water column. Filled bottles were immediately kept on ice until delivery to the Invermere Health Unit located at 110 10 St, Invermere, BC with a copy of each associated requisition form. From there, custody of samples was transferred to the IHA and samples were sent to their labs for analysis.

Data analysis and QA/QC

Raw data were first subjected to a quality control evaluation, to assess the accuracy and validity of the laboratory and field methods. Field sampling protocols followed those outlined above.

Water Quality

For in situ data collection, water quality instruments were calibrated once monthly as per manufacturer's specifications and expired, or outdated solutions were discarded and replaced. All data was reviewed by the LWA for consistency and anomalies before being analyzed. Data was analyzed by plotting parameters over time in Excel, for the current sampling year and past sampling years whenever possible. Geometric means of samples were taken where indicated, and included all samples taken within a 30-day period between start and end of sampling.

CARO laboratory's analysis for Total and Total Dissolved Phosphorous was completed using Persulfate Digestion / Automated Colorimetry (Ascorbic Acid) referencing the Guidelines for Canadian Drinking Water Quality (Health Canada Feb 2017). CARO assessed accuracy through use of laboratory control samples, trip blanks, and duplicate samples.

Aquatic Invasive Plant Survey

Please see Darvill (2022)

Waterbirds

Please see Darvill (2022)

Swim Beaches

Sample results were obtained from the Interior Health Authority (IHA) and analyzed for geometric mean as well as individual sample result over time. Please contact the IHA if you have specific questions about their QA/QC protocol for lab samples.

https://www.interiorhealth.ca/FindUs/_layouts/FindUs/info.aspx?type=Location&loc=Invermere%20Health%20Centre&svc=&ploc=